This supplement accompanies the article

Individual-based modelling of *Calanus sinicus* population dynamics in the Yellow Sea

Luning Wang[1], Hao Wei[2,*], Harold P. Batchelder[3]

[1] College of Physical and Environmental Oceanography, Ocean University of China, Qingdao 266100, PR China

[2] College of Marine Science and Engineering, Tianjin University of Science and Technology, Tianjin 300457, PR China

[3] College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR 97331-5503, USA

*Corresponding author: weihao@ouc.edu.cn

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Supplement 1. The functions and variates in the biological model of *Calanus sinicus*. Further definitions are provided in Supplements 2 & 3

Development

$$D_i = \beta_i \cdot (T + T_b)^{\theta_b} \Big/ (1 - e^{-\kappa \cdot P})$$

$$SD_i = D_{i+1} - D_i$$

$$FD_{t+\Delta t} = FD_t + \frac{\Delta t}{SD_i}$$

i	Stage
T	Temperature (ºC)
P	Food concentration (μg C l^{-1})
D_i	Duration from egg to stage i (days)
SD_i	Duration from stage s to stage i+1 (days)
t	Time (h)
FD_t	Fraction of development completed (nd) at time t

Growth

$$W_{C,t+\Delta t} = W_{C,t} + \frac{dW_C}{dt} \cdot \Delta t$$

$$W_C = W_{C,S} + W_{C,O} + W_{C,E}$$

$$\frac{dW_C}{dt} = G = G_S + G_O + G_E$$

$$G_S = \frac{dW_{C,S}}{dt} = A - R$$

$$A = a_f \cdot I$$

$$I = I_{\max} \cdot I_P \cdot I_W \cdot I_T$$

$$I_P = \varphi_I \cdot \frac{P - P_v}{P - P_v + P_k} \cdot \frac{1}{24}$$

$$I_W = (W_C / W_{C,\max})^{\omega}$$

$$I_T = Q_{10}^{(T - T_{ref})/10}$$

$$R = \varphi_R \cdot q \cdot R_{O_2} \cdot \frac{12}{22.4}$$

$$R_{O_2} = r_0 \cdot W_{D,S}^{\ r_1} \cdot e^{r_2 \cdot T}$$

$$\frac{W_{C,S}}{W_{D,S}} = k_{C2D,S}$$

$$R_{C5d} = k_d \cdot R_{C5a}$$

$W_{C,t}$	Carbon weight (μg C) at time *t*
$W_{C,S}$	Carbon weight of structural body (μg C)
$W_{C,O}$	Carbon weight of lipid (μg C)
$W_{C,E}$	Carbon weight of gonad (μg C)
G	Summed growth rate of carbon weight (μg C h^{-1})
G_S	Growth rate of structural body (μg C h^{-1})
G_O	Growth rate of lipid (μg C h^{-1})
G_E	Growth rate of gonad (μg C h^{-1})
A	Assimilation term (μg C h^{-1})
R	Respiration term (μg C h^{-1})
I	Ingestion term (μg C h^{-1})
I_P	The term of ingestion dependent on food concentration (μg C h^{-1})
I_W	The term of ingestion dependent on weight (nd)
I_T	The term of ingestion dependent on temperature (nd)
$W_{D,S}$	Dry weight of structural body (μg)
R_{C5d}	Respiration of C5 in diapause (μg C h^{-1})
R_{C5a}	Respiration of active C5 (μg C h^{-1})

Diapause

$$\frac{dW_{C,O}}{dt} = G_O = \begin{cases} 0 & (i: N1-N2\ \&\ C6) \\ f_{oil}\cdot G & (i: C3-C5\ \&\ G>0) \end{cases}$$

$$\mathrm{OSV} = 100\% \cdot V_{oil} / V_l$$

$$V_{oil} = W_{W,O} / \rho_{oil}$$

$$\frac{W_{D,O}}{W_{W,O}} = k_{D2W}$$

$$\frac{W_{C,O}}{W_{D,O}} = k_{C2D,O}$$

$$V_l = 0.58 \cdot L_p \cdot d^2$$

$$d = f_{d2l} \cdot L_p$$

$$\log W_C = \ell_1 + \ell_2 \cdot \log L_p$$

After the thermocline appears, transition of active C5s (C5a) to diapausing C5s (C5d) will be entered (C5a→C5d) when $\mathrm{OSV}_{C5a} \geq \lambda_{max}$, or the surface temperature is higher than 20ºC.

Maturation of diapausing C5d to adult females/males occurs when $\mathrm{OSV}_{C5d} \leq \lambda_{min}$ or the thermocline disappears.

When C5 matures into adult female, the lipid in C5 will be converted into the gonad with a fraction f_{O2E}.

$$W_{C,E} = f_{O2E} \cdot W_{C,O}$$

OSV	The lipid/body volume ratio (%)
V_{oil}	Lipid volume (mm^3)
V_l	Body volume (mm^3)
$W_{W,O}$	Wet weight of lipid (μg)
$W_{D,O}$	Dry weight of lipid (μg)
L_p	Prosome length (mm)
d	The maximum width of prosome (mm)

Reproduction

$$\frac{dW_{C,E}}{dt} = G_E = \begin{cases} 0 & (i: Egg - C5 \& C6m) \\ f_E \cdot G & (i: C6f) \end{cases}$$

$$f_E = \begin{cases} 0 & (W_C < W_{C,\min}) \\ \dfrac{W_C - W_{C,\min}}{W_{C,\max} - W_{C,\min}} & (W_{C,\min} \le W_C \le W_{C,\max}) \\ 1 & (W_C > W_{C,\max}) \end{cases}$$

When the gonad matures ($W_{C,E} \geq W_{C,E0}$), a female may produce a clutch of eggs with number $N_{E,\max}$ at local midnight.

$$N_{E,\max} = e_{EP} \cdot (W_{C,E} - W_{C,E0}) / W_{egg}$$

$$e_{EP} = \begin{cases} \min(\varepsilon_1 + \varepsilon_2 \cdot T;\ 1.0) & (T \le T_{e,ref}) \\ \max(\varepsilon_1^{'} + \varepsilon_2^{'} \cdot (T - T_{e,ref});\ 0.0) & (T > T_{e,ref}) \end{cases}$$

The daily egg production follows a normal distribution of clutch size which has a seasonal (surface temperature dependent) mean (μ) and variance (σ). Each superindividual that is a reproductive female each generates a normal random variate at midnight, $N_{E,t} \approx N(\mu_t, \sigma_t)$

which is used to calculate the amount of carbon needed to produce a clutch of $N_{E,t}$ eggs. If sufficient carbon ($W_{C,E}$) is available to produce a clutch of that size, then the clutch is created as a new superindividual of $N_{E,t}$ eggs. If there is not enough carbon, the females of this superindividual wait another 24 hours to try again. $E_t = \sum_n^{N_{f,t}} N_{E,t}$

f_E	Fraction of growth allocated to gonad (nd)
$N_{E,max}$	The maximum number of eggs produced by one female of the superindividual
e_{EP}	Efficiency of conversion of stored carbon into eggs (nd)
N_E	The clutch size of eggs produced by a single female (ind)
$N_{f,t}$	Number of reproductive females at time *t* (ind)
E_t	The total eggs produced by all reproductive females (ind)

Mortality

$$N_{i,t+\Delta t} = N_{i,t} \cdot e^{-M_i \cdot \Delta t}$$

$$M_i = \begin{cases} M_{E,0} + \alpha_N \cdot (N_f + N_{C5}) & (i: Egg) \\ M_{R,i} + M_{starv,i} + M_{abun,i} & (i: N1 - C6) \end{cases}$$

$$M_{R,i} = \begin{cases} M_N & (i: N1 - N6) \\ M_C & (i: C1 - C5a) \\ M_A & (i: C6f) \end{cases}$$

$$M_{R,C6m} = 2 \cdot M_A$$

$$M_{R,C5d} = 0.1 \cdot M_{R,C5a}$$

$$M_{starv,i} = \begin{cases} 0 & (i: N1 \,\&\, N2) \\ 0 & (i: N3 - C6; W_C \geq W_{starv,i}) \\ M_{R,i} & (i: N3 - C6; W_C < W_{starv,i}) \end{cases}$$

$$W_{starv,i} = \zeta_{1,i} + \zeta_{2,i} \cdot T$$

$$M_{abun,i} = \begin{cases} \dfrac{\sum N_i}{N_{ref,i}} & (i: N1 - C6) \\ 0 & (i: C5d) \end{cases}$$

where C5a is expressed as active C5, and C5d as C5 in diapause, and C6f, C6m as female and male adult separately.

$N_{i,t}$	Abundance of individuals in stage *i* at time *t* (ind m^{-2})
N_f	Abundance of females in stage *i* at time *t* (ind m^{-2})
N_{C5}	Abundance of C5s in stage *i* at time *t* (ind m^{-2})
M_i	Mortality (d^{-1})
$M_{R,i}$	Routine mortality of stage *i* (d^{-1})
$M_{starv,i}$	Mortality term dependent on weight (d^{-1})
$W_{starv,i}$	Starvation weight below which the individual is in starvation (μg C)
$M_{abun,i}$	The mortality term dependent on abundance (d^{-1})

Supplement 2. The parameters used in individual-based model of *Calanus sinicus*

Symbol	Description (Unit)	Value
T_b	temperature offset in Belehrádek function (ºC)	0.7
θ_b	curvilinearity in Belehrádek function	-1.44
κ	food dependent parameter for development (l μgC^{-1})	0.033
C:chl	ratio of the concentration of phytoplankton to chl-a	[50-300]; 250
a_f	ingestion assimilation efficiency	0.7
I_{max}	maximum ingestion rate of a 120 μg C female (μg C ind^{-1} d^{-1})	14.79
P_v	threshold concentration below which the feeding will not occur (μg C l^{-1})	3.5
P_k	half saturation concentration for ingestion (μg C l^{-1})	76.8
$W_{C,max}$	maximum carbon weight (μg C)	120
ω	allometric constant for weight dependence of ingestion	0.7
Q_{10}	parameter from van't Hoff equation	2.2
T_{ref}	reference temperature in van't Hoff equation (ºC)	12
φ_R	respiration tuning parameter	[0.5-1.0]; 0.8
q	respiratory quotient (μmol CO_2 μmol O_2^{-1})	0.97 (for carbon) 0.72 (for lipid)
r_0	respiration parameters from Ikeda et al. (2001) (μl O_2 ind^{-1} h^{-1})	0.67
r_1	allometric constant for weight dependence of respiration from Ikeda et al (2001)	0.8
r_2	respiration temperature parameter from Ikeda et al. (2001) (ºC^{-1})	0.069
$k_{C2D,S}$	ratio of structural carbon weight to dry weight	0.4
k_d	ratio of respiration in diapause to that in active phase	0.2
f_{oil}	fraction of growth partitioned into oil body in C3-C5 stages	[0.5-1.0]; 0.6
ρ_{oil}	density of oil (g ml^{-1})	0.9
k_{D2W}	ratio of dry weight to wet weight	0.25
$k_{C2D,O}$	ratio of carbon weight to oil dry weight	0.74
f_{d2l}	ratio of max width to prosome length of copepod	0.3
ℓ_0	parameters in relationship of dry weight with prosome length from Uye (1988)	-9.416
ℓ_1	parameters in relationship of dry weight with prosome length from Uye (1988)	3.378
λ_{max}	threshold of OSV above which diapause begins (%)	[20-40]; 35
λ_{min}	threshold of OSV below which the diapause ends (%)	5
f_{O2E}	fraction of residual oil in C5 transferred into gonad weight when molting to adult female	0.5
$W_{C,min}$	minimum weight of an adult female (μg C)	40
$W_{C,E0}$	minimum gonad weight allowing reproduction by adult	10

	female (μg C)	
W_{egg}	carbon weight of an egg (μg C)	0.3
ε_1	intercept parameter in equation of efficiency of conversion of stored carbon into eggs for $T \leq T_{e,ref}$	5.5
ε_2	slope parameter in equation of efficiency of conversion of stored carbon into eggs for $T \leq T_{e,ref}$ (°C^{-1})	-0.3
ε_1	intercept parameter in equation of efficiency of conversion of stored carbon into eggs for $T > T_{e,ref}$	0.4
ε_2	slope parameter in equation of efficiency of conversion of stored carbon into eggs for $T > T_{e,ref}$ (°C^{-1})	-0.0308
$T_{e,ref}$	reference temperature in equation of efficiency of conversion of stored carbon into eggs (°C)	17
μ	mean clutch size (eggs clutch^{-1} female^{-1})	11.34 ($T > 15$°C); 31.34 ($T \leq 15$°C)
σ	variance of clutch size (eggs clutch^{-1} female^{-1})	1.47 ($T > 15$°C); 10.18 ($T \leq 15$°C)
$N_{EP,max}$	maximum number of lifetime clutches produced by a female	20
$M_{E,0}$	base mortality of eggs (d^{-1})	0.35
α_N	density coefficient (m^2 ind^{-1})	8×10^{-5}
M_N	routine mortality of nauplii (d^{-1})	[0.005-0.05]; 0.04
M_C	routine mortality of copepod (d^{-1})	[0.005-0.05]; 0.02
M_A	routine mortality of female adult (d^{-1})	[0.005-0.05]; 0.02

Supplement 3. Stage-specific parameters used in individual-based model of *Calanus sinicus*

Symbol	Description	N1	N2	N3	N4	N5	N6	C1	C2	C3	C4	C5a	C6
β_i	parameter in Belehrádek function (days)	55.3	93.1	139.7	284.2	356.9	445.0	528.0	631.4	733.3	853.3	982.5	1258.0
$\varphi_{I,i}$	parameter in ingestion equation (nd)	0	0	1.0	1.0	1.0	1.0	1.5	1.5	2.0	2.0	1.5	1.0
$\zeta_{1,i}$	parameter in equation of starvation weight (μg C)	0	0	0	0.14	0.22	0.36	0.49	0.72	1.82	0.23	16.70	35.13
$\zeta_{2,i}$	parameter in equation of starvation weight (μg C °C^{-1})	0	0	0	0	0	0	0	0	0	–0.12	–0.42	–0.83
$N_{ref,i}$	reference abundance in the abundance-dependent mortality (10^5 ind m^{-2})	10	10	10	10	10	10	5	5	5	5	5	5